Semiconductor Structure with Active Zones

The invention relates to a semiconductor structure with active zones, according to the preamble to Claim 1 or the preamble to Claim 2.

A semiconductor structure with active zones according to the preamble to Claim 1 is known, for example, from an article by J.P. Contour, i.a. "(GaAl)As tunnel junctions grown by molecular beam epitaxy: intercell ohmic contacts for multiple-band-gap solar cells", IEE, Stevenage, GB, November 1984. Described is a semiconductor structure with epitaxially grown optoelectronic active zones that lie one on top of another and are connected to one another by isolation diodes, wherein each active zone has a higher energetic band gap than the active zone beneath it, and the semiconductor materials of the isolation diodes have an energetic band gap that in each case is somewhat higher than that of the semiconductor materials that lie beneath it.

From US-A-5,166,761 a multi-wavelength diode with a monolithic, cascading cell structure is also known, comprising at least two p-n junctions, wherein each of the at least two p-n junctions has essentially different band gaps, and electrical connection elements are supplied with energy together through the at least two p-n junctions, and wherein the diode comprises a tunnel junction.

A semiconductor structure with active zones according to the preamble to Claim 2 is described in EP-B-0 649 202. This is related to a semiconductor laser and the method for producing said laser. The semiconductor laser comprises a multitude of semiconductor chips layered one on top of another by soldering such that their laser radiation surfaces are arranged coplanar to one another, wherein each laser chip has a substrate

with epitaxial layers applied thereon, including one active layer.

Another semiconductor structure with active zones is described in an article by I. Ozden, et al.: "A dual-wavelength indium gallium nitride quantum well light emitting diode" in Applied Physics Letters, Vol. 79, No. 16, 2001, pp 2532 - 2534. This article deals with a monolithic, dual wavelength (blue/green) light-emitting diode (LED) with two active indium-gallium-nitride/gallium nitride (InGaN/GaN) multiple quantum well segments. The segments are part of a single vertical epitaxial structure, in which a p^{++}/n^{++}/InGaN/GaN tunnel junction is inserted between the LED's. The segments emit at 470 nm and 535 nm, respectively.

EP-A-1 403 935 describes a light-emitting diode with a first active zone, a second active zone and a tunnel junction. The tunnel junction comprises one layer of a first conductive type and one layer of a second conductive type, both of which are thinner than one layer of a first conductive type and one layer of a second conductive type, which encompass the first active zone. The tunnel junction permits the vertical stacking of the active zones, whereby the light that is generated by the element can be increased without increasing the size of the light source.

EP-A-0 727 830 relates to a method for producing a light-emitting diode (LED) with multiple layers comprising adjacent first and second layers, which are connected to a connecting piece. Production can be carried out according to the wafer-bonding method. Multiple LED structures can be connected with other layers if the intermediate layer is designed such that a high degree of electrical conductivity through the element is ensured. The type of doping in the layers of the upper LED structure corresponds to the type of doping type in the layers of the lower LED structure. Thus the two LED structures are arranged with the same polarity relative to one another. The surfaces to be bonded to one another (wafer bonding) should be very highly doped. When the structures are bonded, a highly doped tunnel junction with opposite

polarity of the LED's is formed. As an alternative it is proposed that the tunnel junction is grown epitaxially.

From WO-A-00/77861 a semiconductor structure with active zones is known, comprising a multitude of active layers that are selective for various wavelengths, which layers are arranged in a vertical stack on a substrate, so that the incident light is able to pass through the layers with evenly decreasing band gaps. Photons of differing energy are selectively absorbed or emitted by the active layers. Contact elements are arranged separately on the outer sides of each layer or a set of layers having the same parameters, in order to remove the charges that are generated in the photon-absorbing layers, and/or to introduce charge carriers into the photon-emitting layers. This element is intended for use, for example, in displays or solar cells.

From WO 99/57788 a further light-emitting semiconductor device of the type described above is known. In this publication a dual-color light-emitting semiconductor device is described, which has, between its front side and its back side, a first surface-emitting light-emitting diode with a first active zone, which emits radiation of a first wavelength, and a second surface-emitting light-emitting diode with a second active zone, which emits radiation of a second wavelength, wherein between the two active zones a first reflective layer is arranged, which is reflective for the first wavelength and is transparent for the second wavelength. It is further provided that between the second active zone and the back a second reflective layer is arranged, which is reflective for the second wavelength. The reflective layers result in improved utilization of the light from both diodes that is radiated in the direction of the back and are preferably formed from a multilayer system of layers with alternating high and low refractive indices, wherein the layers are preferably constructed from a semiconductor material adapted to a lattice.

In the prior art semiconductor device, the active zones are applied to two opposite surfaces of a substrate, so that a beam of light emitted from the lower active

zone must pass through the substrate and at least one reflective layer, whereby optical losses are possible. Furthermore, with the known light-emitting semiconductor device, only two light beams can be generated. Thus its use in a colored display is limited.

Based upon the above, the object of the present invention is to further develop a semiconductor structure with active zones such that an intensity adjustment of the emitted light of the relevant active zone is achieved.

The object is attained according to the invention in that on an active zone an absorption layer having the same material as the pn layer of the active zone is grown. This is done for the purpose of adjusting the intensity of the emitted light from the relevant active zone in the case of serial connection.

With the light-emitting semiconductor device of the invention, which can also be characterized as a multi-wavelength diode, multiple photon emission peaks of differing wavelengths can be generated within one chip. The principle is based upon the fact that epitaxial semiconductor materials are grown on a suitable substrate. The light-emitting active zones, which are designed as pn or np junctions, are serially connected from the bottom to the top in the chip. Thus the connection is implemented epitaxially via dividing layers, such as isolation diodes, which are used as low-impedance resistors. These isolation diodes are comprised of an np or pn junction, on which a very low, opposite voltage falls.

The alternative embodiment provides that a conductive, for example a metallic, contact is used as the intermediate layer for the serial connection.

It is provided that the material of the substrate is GaAs, Ge, InP, GaSb, GaP, InAs, Si, SiGe, SiC, SiGe: C, sapphire, or diamond.

It is further provided that the material of the active zones is or contains one or more of the following materials: GaAs, GaInP (suitable compositions), AlGaAs (many suitable compositions), GaInAs (suitable compositions), AlInGaP (many suitable compositions), GaAsN, GaN, GaInN, InN, GaInAlN (suitable compositions), GaAlSb, GaInAlSb, CdTe, MgSe, MgS, 6HSiC, ZnTe, CgSe, GaAsSb, GaSb, InAsN, 4H-SiC, a - Sn, BN, BP, BAs, AlN, ZnO, ZnS, ZnSe, CdSe, CdTe, HgS, HgSe, PbS, PbSe, PbTe, HgTe, HgCdTe, CdS, ZnSe, InSb, AlP, AlAs, AlSb, InAs and/or AlSb.

A band emission diode is characterized by the following structure:

- a GaAs or Ge substrate,
- a GaAs diode (lower diode) that is grown on the substrate,
- on top of this, in alternating sequence, an isolation diode, such as a GaInP isolation diode or an AlGaAs isolation diode, that is grown on the GaAs diode, followed by a GaInP diode or AlGaAs diode that is grown on the isolation diode, with the number of diodes (AZ1 - AZn) defining the number of peaks in a band emission range.

The band emission range is defined in that the number of diodes and the number and width of the peak structure form a coincident light emission range in a way that could not be achieved with a single peak, thus a resulting emission range is obtained.

Each of the individual active zones can also be equipped with metallic contacts of their own for connection to a connecting lead, for cases in which each active zone or selected individual active zones are to be separately activated.

A blended-color LED colored brown with only one chip preferably has the following structure:

- a GaA or Ge substrate,
- a lower active zone, grown on the substrate, made, for example, of GaInP (also AlGaInP), whose suitable emission wavelength lies within the red range,

- a first isolation diode made of GaInP or AlGaInP, grown on the lower active zone, whose band energy is higher than that of the active zone beneath it,
- a center active zone made of AlInGaP, grown on the isolation diode, whose emission wavelength lies within the yellow range,
- a second isolation diode and whose band energy lies below the band energy of the active zone beneath it and
- an upper active zone made of AlInGaP, grown on the second isolation diode, whose emission wavelength lies within the green range.

Another preferred embodiment is characterized in that a blended-color LED comprises:

- a GaAs or Ge substrate (SUB),
- a lower active zone (AZ1), grown on the substrate, followed by two additional active zones (AZ2 - AZn), between which a tunnel diode (TD1 - TDn) is arranged, wherein the upper active zone (AZn) has a metallic contact (K) for connection with an electric terminal.